

XMM-NEWTON CALIBRATION - AN OVERVIEW

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ABSTRACT

This paper introduces the articles that describe detailed aspects of the XMM-Newton calibration. The unique calibration issues of XMM-Newton are highlighted. The original calibration requirements and aspects of the ground calibration are summarized. The life cycle of the in-orbit calibration observations, analysis and ingestion into calibration files is discussed

Key words: Missions: XMM-Newton

1. THE ORIGINAL CALIBRATION REQUIREMENTS

The mission science goals were defined more than 15 years before launch. During the hardware development phase these were used to form a set of requirements for calibration accuracy that guided the design of facilities and activities for the instrument calibration (Erd et al 1996). With the benefit of hindsight it was realised that the change in some aspects of projected performance of the delivered hardware undermined or superceded some of those goals. For example the significantly improved telescope resolution demands much greater astrometric reconstruction and PSF knowledge than was envisaged some years ago, when it was by no means certain the goal of 20 – 30 arcsecs Half Energy Width would be met! Nevertheless those sets of requirements have remained broadly appropriate (see Table 1), and it is instructive to recall them in order to judge the success of our existing activities.

At the same time there was a widely held opinion that there was no need to calibrate XMM on-ground to such accuracies, because XMM would be contemporaneous with an AXAF observatory which would be “*calibrated to 1%*”, and therefore XMM needed only to be cross-calibrated to AXAF. Needless to say that approach was not adopted.

2. STATUS AT LAUNCH & CAL/PV PHASE

The usual realities of the flight hardware programme contributed to a lowering of expectations, not least for the calibration accuracy. As ever there was not enough time to complete the designed calibration measurement programme.

One problem was that of late deliveries. At a late stage the PN camera Flight Model suffered a failed CCD, and was replaced with the Flight Spare camera (which eventually turned out to be physically different from the original). There was a need to replace some of the CCDs in the MOS cameras, even swapping one complete focal plane. The OM began a late replacement programme for its mirrors, leading to a limited test programme time, which affected the calibration of filters and stray light testing. Overall the in-flight calibration campaign did not have the sound under-pinning of a successful ground calibration programme that had been anticipated. On the other hand, the multiple similar instrument deployment approach *has* meant that there is strong heritage from one version of a camera to the other which recovers some of this loss.

The in-flight calibration programme was scoped in quite some detail somewhat before launch in order to ensure that an efficient completion of the complex measurement programme could be planned for. However, it was not known if the Ground Segment would support this plan, as it was never the subject of end-to-end tests before launch. As a result the celestial calibration programme was severely curtailed by the eventual low efficiency of operations in the early mission phase. Such aspects as needing to develop functionality (Observation Data File availability, missing Attitude History Files etc.), as well as developing workarounds and changing the instrument operations and settings to accommodate instrument anomalies, were all carried out during the nominal calibration phase.

In reality then, we have been faced with building up the calibration knowledge during the course of normal observations of GT and GO targets, so that the availability of improving knowledge lags behind the expectations.

The internal instrument in-flight calibration sources have limited energy leverage, so that their use for confirming energy scales and understanding effects of gain stability is less than anticipated. Most efforts therefore rely on celestial targets, none of which could be described as “*standard candles*”.

Despite all these difficulties, the instrument teams have laboured to develop an understanding of the instrument calibration, whose knowledge at one year post-launch is captured in the accompanying documents, and which it should be judged, compares favourably with the original goals laid out.

Table 1. Summary of major calibration requirements

Parameter	Requirement	Notes	Achieved
Astrometry	≤ 3 arcsec	Allows ground based follow-up with low confusion probability	1 arcsec if field source IDs available
Absolute eff. area	10%	Long term variability studies Observatory cross-calibrations	5 – 10% (0.5 – 7 keV)
Relative eff. area	3%	Robust spectral fitting	Typically 2%, 5% at edges?
Energy calibration	3eV EPIC, better than 10mA RGS	Broadening and bulk motions limited by statistics only	Not achieved for all modes Some bright SNR require ≤ 3 eV
Timing	1 msec	Fast CCD readouts would allow spectrally resolved light curves	Internally 10 μ sec Limited by Orbit knowledge TBC
OM photometry	10 mMag	Populations and variability	Relative stability OK Completing the colour transforms per filter
OM astrometry	1 arcsec	Source ID in crowded fields	1 arcsec if field source IDs available

3. UNIQUES FEATURES OF XMM-NEWTON

It is perhaps worth reiterating some of the exceptional features of the XMM-Newton payload which pose some very particular challenges for the calibration activity.

- The unprecedented large effective area means that the photon statistics imply systematic errors are revealed BEFORE they would be in other observatories. Also the improved S:N pushes new astrophysics models, necessitating better calibration
- The co-aligned instruments operate simultaneously - while this in principle allows to cross-check between instruments, it also demands from observers that the cross-calibration is secure
- Filter choices: EPIC for example can select from THIN, MEDIUM or THICK, and OM has multiple positions for filter photometry. These require a multiplicity in calibration activity and understanding
- Instrument modes: there are different modes for count rate optimisation : EPIC offers IMAGING, WINDOW and TIMING modes. The OM also offers fast and windowed operation to its nominal mode. Again a multiplicity of calibration is imposed, compounded by the need to use windowed modes in these instruments for bright high S:N sources.

4. CALIBRATION LIFE-CYCLE

There are scheduled routine and periodic calibrations to check the stability of gain, wavelength scale, CTI, astrometry etc.. Thereafter we define non-routine observations to

investigate anomalies. The mission planning cycle is a first limit to the speed of implementation, especially where visibility of a chosen target may be limited. Recent experience shows anODF will become available ≤ 1 month after the observation. The instrument teams then analyse this data. If the improved understanding or models are forthcoming, it can frequently occur that new interfaces in SAS tasks or via. the "*Calibration Access Layer*" may be needed. Such new tasks require that adequate testing will occur before the implementation in the next public release of SAS. Thus it is easy to comprehend the low efficiency of the cycle of updates that sometimes occurs.

As well as the activity in the instrument teams, the calibration effort is supported by the SOC team who man the Help Desk and enter the CCF files and generate the Release Notes explaining the changes to the calibration data.

4.1. CURRENT CALIBRATION FILE

In the simplest cases, the review of calibration analysis leads only to an improved knowledge of exiting calibration models, and only a data set update is necessary. In the XM-Newton SAS environment these calibration sets are known as the "*Current Calibration File*".

Release notes are published with each new CCF set to explain what has changed and the science impact. This means that the user can judge if his/her data needs to be reprocessed. The *CALVIEW* task can be used to plot out and export data as interpreted by SAS Calibration

Access Layer calls. This is an additional useful aid for understanding the impact of various calibration data.

Users should be aware of the *CIFBUILD* task, and ensure to run this task to get complete new CCF set aligned for reprocessing of data sets. It is also possible to run individual tasks with the *-ccffiles"xxx.CCF"* option, just to see the effect on one task, of a changed calibration file. 'xxx.CCF' represents the full name and path of a single calibration file. Finally we recommend that users subscribe to the calibration mailing list for prompt notification of CCF updates.

5. OUTLOOK

The existing calibration is clearly adequate to support a host of science papers that are now being produced from XMM observations. Cross-calibration between the instruments of XMM-Newton is excellent with the exception of the extreme energy ranges. As noted by Snowden in this volume, there is also an acceptable cross calibration between EPIC and other observatories. The status of the knowledge presented herein is expected to be accounted for in the next public release of SAS (version 5.3 at time of writing).

However it was evident from some presentations at this workshop that new science analysis (for example subtle effects in the iron line details in AGN) afforded by the unrivalled XMM-Newton collection area are demanding yet higher calibration accuracy. The instrument teams have committed significant teams of expertise to support the continued improvement in understanding the calibration of their hardware, so that we expect a continual evolution in this knowledge through the extended mission duration.

REFERENCES

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